Update on low-Q^2 tagger

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Far-Forward Detectors Meeting

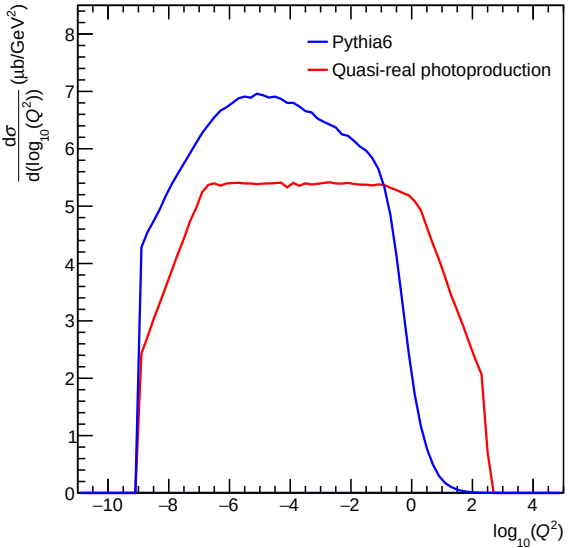
Outline

1. Update on acceptance plots, following the Pavia meeting here
   - Comparison between Pythia6 sample and quasi-real generator
   - Coverage in x and Q^2 and in x and y will be shown here
2. Limits to possible Q^2 reconstruction due to angular divergence, following previous presentation at far-forward meeting here
   - It was shown in the slides above that the electron Q_e^2 can be reconstructed down to $Q_e^2 \sim 10^{-5}$ GeV^2 using energy and hit position on the tagger
   - The electron Q_e^2 is given by its energy and scattering angle:

$$Q_e^2 = 2EE'\,(1 - \cos(\theta_e))$$

   - Relation between true Q^2 and electron Q_e^2 is affected by beam angular divergence already at $Q^2 \sim 10^{-3}$ GeV^2
   - In the following, Q^2 will denote the generator true Q^2 and Q_e^2 will be the electron Q_e^2
   - Effect of the divergence to resolution in Q^2 will be shown

Cross section as a function of true Q^2



- Cross section in Q^2 for Pythia6 and quasi-real photoproduction for 18x275 GeV beams
- Total Pythia6 cross section is 54.7 μb
- Total quasi-real cross section is 53.8 μb
- Range in x and y for the quasi-real generator was set according to the Pythia6 sample

Generator true x and y

Figure: Pythia6

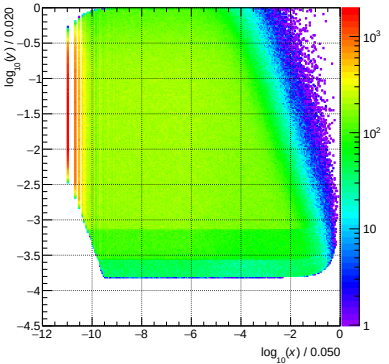
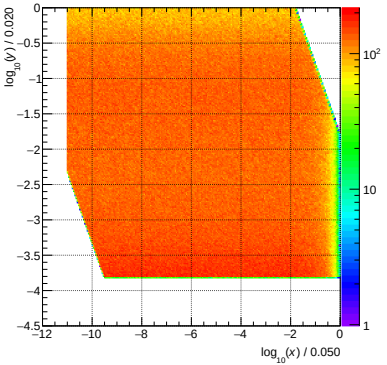


Figure: Quasi-real photoproduction



- Samples of 5M events for Geant4 simulations
- Bands in x in Pythia6 sample are a result of ascii precision
- Logaritmically-uniform shape for quasi-real events

Generator true x and Q^2

Figure: Pythia6

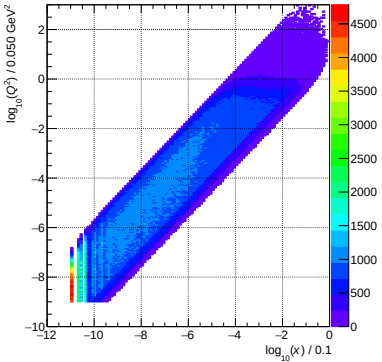
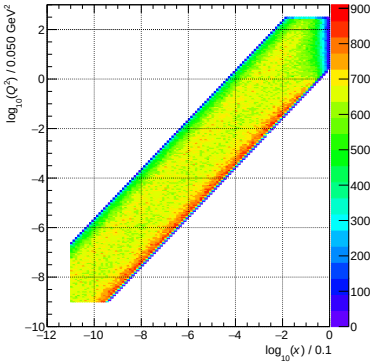
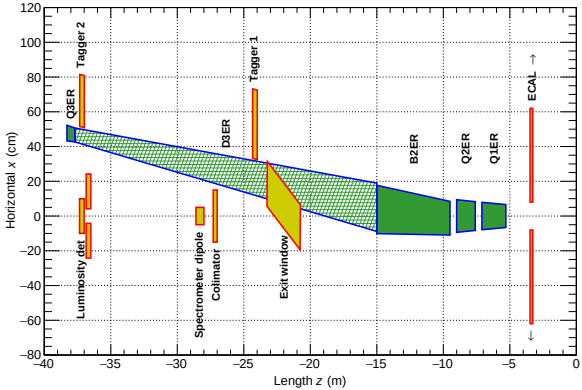


Figure: Quasi-real photoproduction



- Same samples as on previous page
- More uniform shape with quasi-real events

IR layout, electron outgoing side



- The ECAL is placed at $z = -3.28$ m, tagger 1 and 2 at z = -24 m and -37 m respectively
- Preliminary positions, getting fixed from synrad simulations and beam pipe design
- All components shown here are implemented in Geant4 model, with D3ER drift space transparent

Angular and energy coverage for the taggers and ECAL

- Scattered electron energy and angle for events with a hit in one of the taggers and ECAL

Figure: Tagger 1

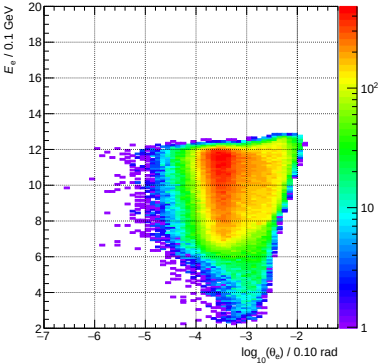


Figure: Tagger 2

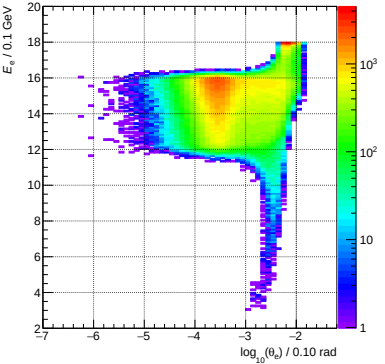
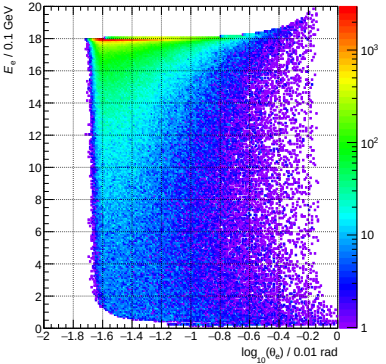


Figure: ECAL



Detector coverage in Q^2 and electron Q_e^2 with Pythia6

Figure: Pythia6 true Q^2

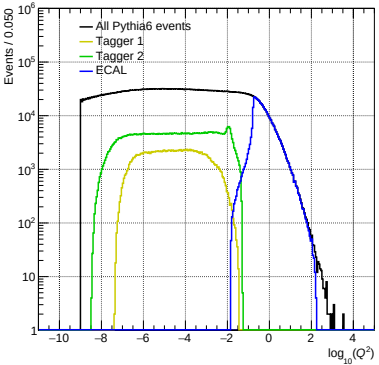
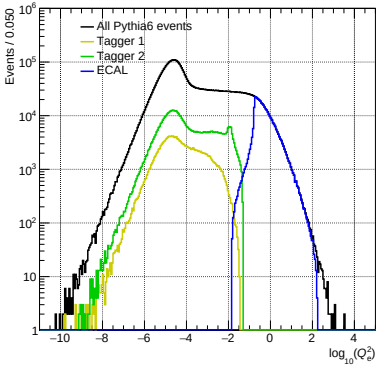


Figure: Electron Q_e^2 from Pythia6



- True Q^2 and Q_e^2 for all generated events and for events with a hit in one of the taggers or ECAL separately
- Presence of angular divergence changes the shape of Q_e^2

Detector coverage in Q^2 and electron Q_e^2 with quasi-real events

Figure: Quasi-real true Q^2

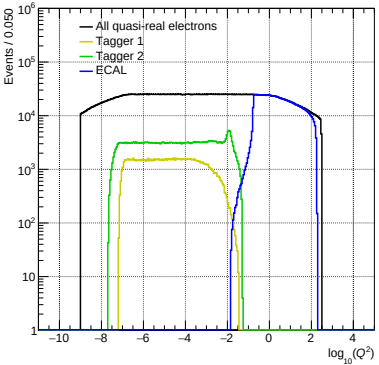
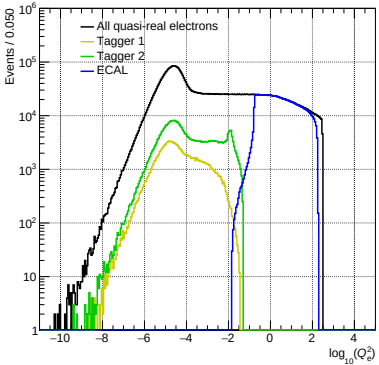
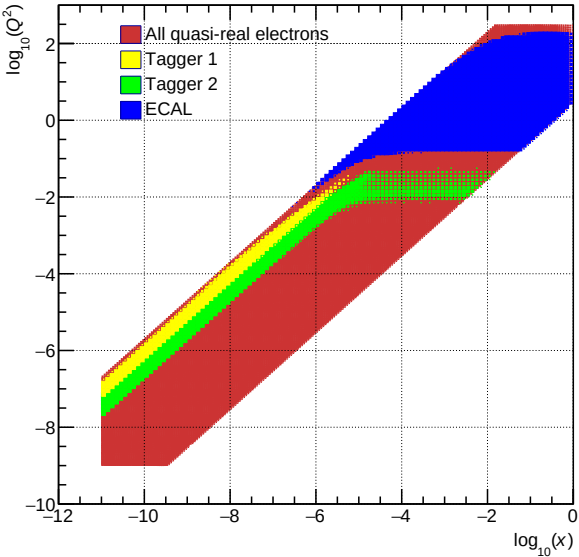


Figure: Electron Q_e^2



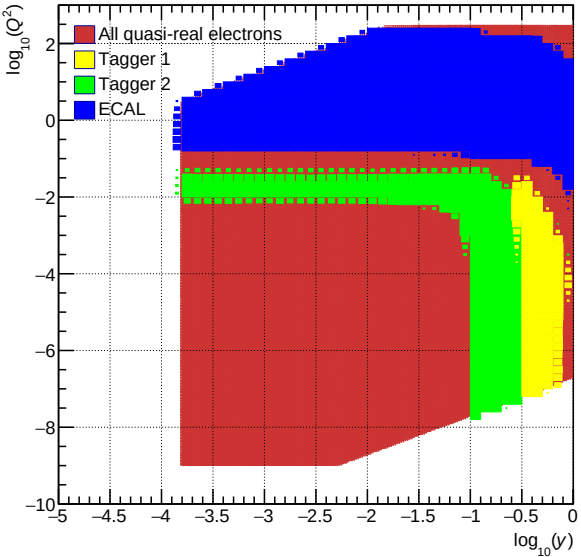
- True Q^2 and Q_e^2 for all generated events and for events with a hit in one of the taggers or ECAL separately
- Similar observation in the shape change as with Pythia6

Coverage in x and Q^2



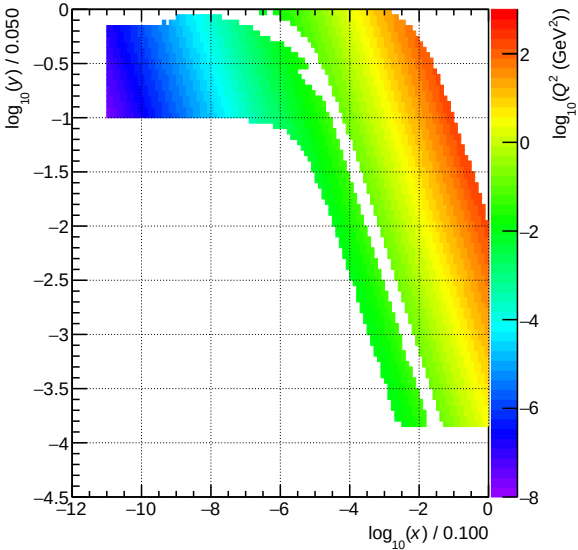
- Red band gives all generated events
- Box diagrams show events with a hit in one of the taggers or in ECAL

Coverage in y and Q^2



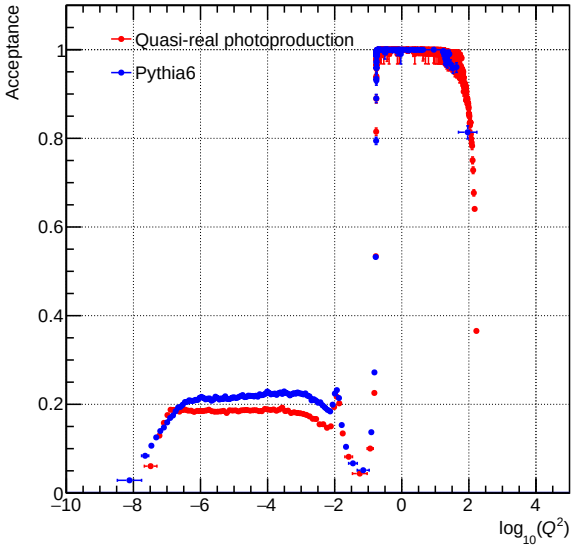
- Red band gives all generated events
- Box diagrams show events with a hit in one of the taggers or in ECAL

Coverage in x and y with Q^2 shown as color scale



- Events with a hit in one of the taggers or in the ECAL
- Color scale gives the Q^2 at a given x and y

Acceptance in Q^2 with Pythia6 and quasi-real events



- Fraction of events with a hit in one of the taggers or ECAL
- Compatible with both events generators

Effect of angular divergence to electron Q_e^2

Figure: With angular divergence

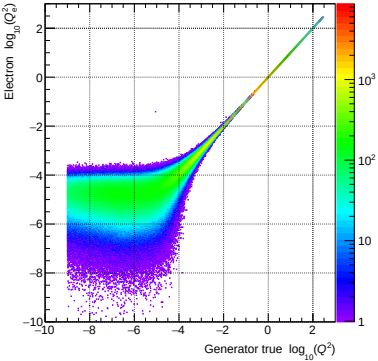
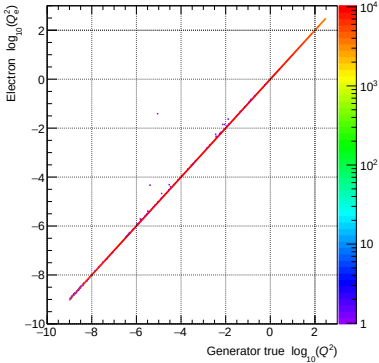


Figure: No divergence



- Electron Q_e^2 is proportional to the true Q^2 to 10^{-3} GeV^2
- At lower Q^2 the correspondence is lost
- When the divergence is removed, the Q_e^2 and Q^2 are identical

Possible resolution in Q^2 in the presence of divergence

Figure: Tagger 1 and 2

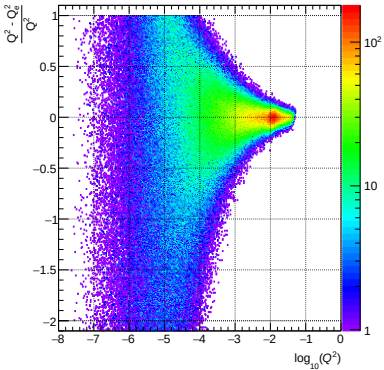
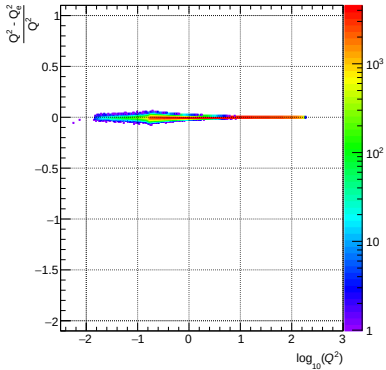


Figure: ECAL



- Relative difference between the electron Q_e^2 and true Q^2:

$$\frac{Q^2 - Q_e^2}{Q^2}$$

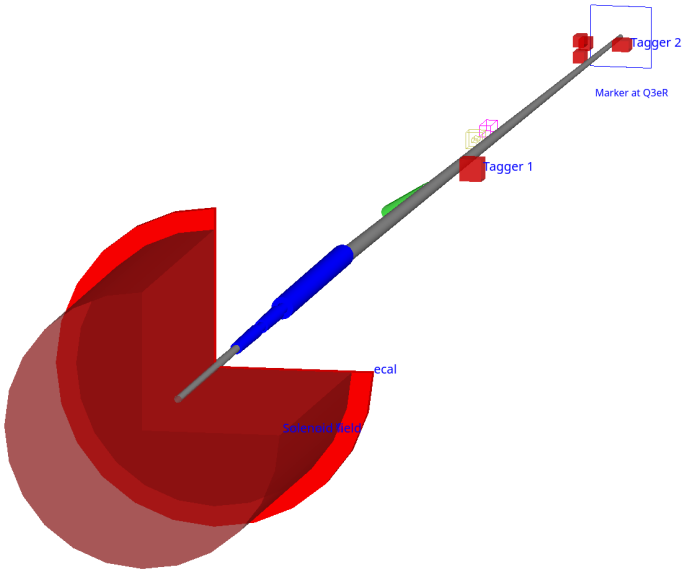
- Shown as a function of true Q^2 for events with a hit in one of the taggers or in ECAL
- No issue for ECAL
- Strong limits to the taggers

Summary

- Taggers and ECAL coverage was shown in x and Q^2 and x and y
- Acceptance is compatible between Pythia6 and quasi-real generator
- Total cross sections agree between the Pythia6 and quasi-real samples
- Location of individual elements is getting fixed according to synrad and beam pipe design
- Electron Q_e^2 stops to give the true Q^2 at very low Q^2 as a result of angular divergence
- Still several bins will be possible using the taggers
- Next steps are aimed to setting a more realistic layout and getting event rates both for signal events and for bremsstrahlung background
- Pythia6 sample used with this study is here: /eicdata/eic0009/PYTHIA/ep/TXTFILES/pythia.ep.18x275.5Mevents.1.RadCor=0.Q2.all.txt
- Quasi-real generator is implemented here: github.com/adamjaro/eic-lgen
- Geant4 and analysis codes are here: github.com/adamjaro/lmon

Backup

Geant4 model for electron-outgoing IR



- Drift spaces in grey are transparent to all particles
- Tagger 1,2 and ECAL detectors mark hits by incoming particles
- Solenoid field uses the BeAST parametrization
- Beam magnets are shown in blue
- Components of luminosity monitor are on the opposite side to the taggers
- The layout ends with a marker at Q3eR position

Hit positions on the taggers and ECAL

- Simulation of scattered electrons from 5M Pythia6 events, energy 18x275 GeV
- Beam effects of vertex spread and angular divergence in x and y are included
- Positions where the scattered electrons hit the front face of the detectors are shown below

Figure: Hits in tagger 1

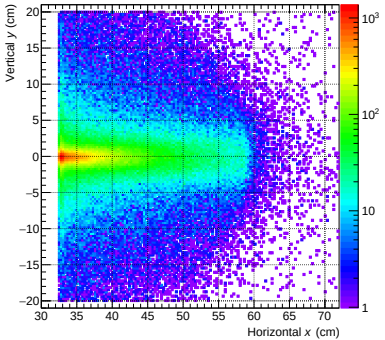


Figure: Hits in tagger 2

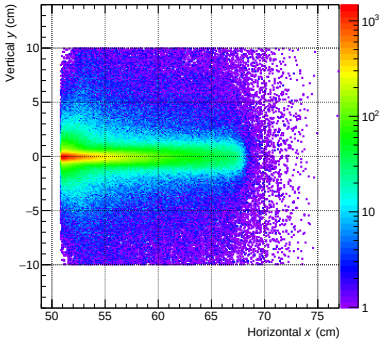
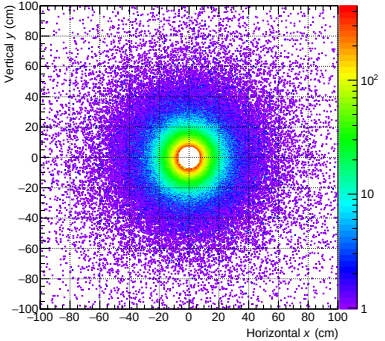


Figure: Hits in ECAL



Beam effects in eic-lgen event generator

- Vertex spread with Gaussian beam profile
  - Driven by emittance in x and y and bunch length in z
  - Vertex positions are generated from Gaussians in x, y and z of a given width $\sigma_{x,y,z}$
  - Using pCDR high acceptance configuration without hadron cooling for 18 x 275 GeV ep beams:
  - IP RMS beam size is σ_x = 236 µm and σ_y = 16.2 µm, RMS bunch length is σ_z = 1.7 cm
- Angular divergence
  - Separate for horizontal and vertical divergence
  - Implemented as Gaussian rotations of particle 3-momentum in x and y
  - The specific angles are generated with pCDR RMS values of $\sigma_{\theta,x}$ = 163 µrad and $\sigma_{\theta,y}$ = 202 µrad
  - Improvement over the initial studies on luminosity monitor, where only a single σ_θ was used for Gaussian smearing of electron polar angles
- For Pythia6 events the beam effects are implemented with an afterburner approach on the scattered electrons

Model of quasi-real photoproduction in eic-lgen

- Event generator implemented to *lgen* using one photon exchange cross section from HERA study in Conf.Proc. C790402 (1979) 1-474
- The parametrization for quasi-real photoproduction in low-Q^2 approximation (Eq. II.6 in HERA study) is

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}x\mathrm{d}y} = \frac{\alpha}{2\pi}\,\frac{1+(1-y)^2}{y}\,\sigma_{\gamma p}(ys)\,\frac{1-x}{x}\;(\mathrm{mb}) \tag{1}$$

- The total photon-proton cross section $\sigma_{\gamma p}$ is used from Regge fit in Phys.Lett. B296 (1992) 227-232:

$$\sigma_{\gamma p}(ys) = 0.0677(ys)^{0.0808} + 0.129(ys)^{-0.4525}\;(\mathrm{mb}) \tag{2}$$

- Equation 1, with input from Eq. 2, is used to generate values of Bjorken x and inelasticity y
- Kinematics is then applied to generate the electrons with output to ROOT, TX or Pythia6 format
- Similar procedure was used for H1 low-Q^2 tagger in H1-04/93-287 (1993)